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Impact of structuring networks on fight against flooding in Grand Yoff, Dakar, Senegal

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Abstract— **Grand Yoff, like many localities of niayes area, in Senegal, has experienced devastating floods in 2005, 2009 and 2012. The Senegalese authorities have long opted for the emergency solution what is to set up pumps to relieve populations rainwater invading. But since October 2012, the State of Senegal has established a Ministry of the Restructuring and Spatial flood zones (MRAZI) to ensure the well-being of people living in these areas. The state has also pledged to take measures to reduce the risk of flooding by raising regulatory, and to get financial means in order to achieve structuring networks that could bring lasting solutions to the fight against floods. The EPA SWMM software used for the simulations shows that the existing system was outdated and some structuring works made recently are at risk of overflowing with a decennial rain Kiefer type.**

Index Terms— **fight, flood, structuring networks, Grand Yoff, Dakar**

I. INTRODUCTION

The corollary of all urban sanitation policy is the realization of structural works and other equipment necessary for the life of communities [1]. This objective entails, for Senegal State, local authorities and development partners, the development and implementation of the orga-nization plans to fight effectively against floods and environmental degradation of cities. However, the rains, the occupation of the lowlands as well as non-building areas by the population, the rural exodus and population growth do not facilitate this policy [2], [3], [4], [5], [6], [7], [8]. These are the reason why soil sealing participating in the traditional increase in runoff and impacts the calculation conditions developed during the sizing of structuring networks [9], [10], [11], [12], [13], [14]. This situation does not leave indifferent Grand Yoff because of rapid population growth, due to poor servicing of certain neighborhoods located in an area in the form of bowl facilitating water stagnation that can create flooding [12], [13]. In fact, floods are among the major problems facing the State of Senegal and some local communities face at least once during each wintering period and have been for over a decade [12], [13]. It is a complex phenomenon whose solutions are difficult to grasp. Thus, rainwater drainage works are made in several urban centers such as Grand Yoff in the department of Dakar. It is in this context that the Government of Senegal, in October 2012, created a Ministry for the Restructuring and Spatial flood zones (MRAZI) to ensure the well-being of people living in these areas. The overall objective of this article is to analyze the impacts of structuring works in place for the fight against floods in Grand Yoff. Those structural networks should relieve the surrounding populations in exceptional rain if properly sized and well maintained [12], [13], [14].

II. MATERIALS AND METHODS

1.1. Presentation of the study area

1.1.1. geographical position of the site

The town of Grand Yoff covers an area of 6.3 km^2. Its administrative boundaries are: at north, by Airport Road between the roundabout of the Patte d'Oie and the interchange of the Fair; at west, by the Way of North Clearance (VDN) to its intersection with the road to the Front de Terre; at south by road from the Front de Terre to the interchange of Hann and at east by Highway interchange between Hann and the round about of the Patte d'Oie (Figure 1).

Figure 1: Location of the town of Grand Yoff

1.1.2. physical presentation of the site

Grand Yoff is built on a rugged terrain ranging from 48 m to 6 m having to within a basin which is the natural receptacle of rainwater. Hydrography is essentially composed of Lake ORYX (catchment area) which drains almost all rainwater catchment Grand YOFF through a drainage of rainwater [12], [13].

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1.2. History rainwater drainage projects of Grand Yoff

With urbanization, the green surfaces decrease leaving in place a clear expression of spatial namely infrastructure and housing [12], [13]. Over the years, the Watershed Urban Grand Yoff (BVUGY) had a disturbing pace of urbanization, resulting in sealing of the area and an increasing runoff coefficient too. This basin is drained by the lake ORYX (catchment area) located near the highway. The unplanned urbanization has not spared this lake because populations have almost filled in to build houses [12], [13]. Now this lake has the essential function of serving undercover area for all rainwater drained from Grand Yoff, the Front de Terre, Castors, Liberté 6 and Khar yalla, for groundwater recharge. To make water drainage to the lake, the Senegalese authorities have undertaken towards the 1993 major water drainage projects to develop, besides the basin of the lake area, a network of three lines: the Front de Terre channel that drains rainwater of Castors, Sicap Liberty 5 and 6, Khar Yalla. It is a rectangular channel of 6.00 m x 1.80 m; two twin pipelines, each with a diameter of 800 mm, gravity draining rainwater and wastewater Grand YOFF south towards the lake; a 600 mm pipe diameter draining through a pumping station, storm water Grand YOFF north. With urbanization, the area, which has rarely experienced a flood, hit the headlines during the month of August 2005[12], [13].Indeed, in the week of August 16 to 22, 2005, rainfall the order of 188 mm fell on Dakar and its surroundings, causing the flooding of vast areas, with the consequences, moving much of the population of the affected areas (city Bellevue, Grand Yoff, Yoff, etc.) a lot of inconvenience in urban mobility, especially at the low point of the highway (city Belle Vue, etc.) and property damage[12], [13].Then, many of Grand Yoff drainage network extension work was carried out including increasing the capacity of the pumping system to avoid overflows in the impoundment. Thus, a pumping system to drain excess water to the sea with a pump that operates daily during 22 h debiting and 950 m^3 / h, was set up. There was also flooding in 2009 and 2012, which has further pushed the administrative authorities to trigger ORSEC third of its kind to relieve populations under water. In 2013, a ten-year plan against floods was implemented, which allowed the reconstruction of Grand Yoff storage basin with the installation of two pump unit flow 1350 m^3 / h in the new pumping tank, laying two parallel pipes 500 mm diameter between the Grand Yoff basin and that of the catchment area in which repress both cited pumps, sewage storage tank and raising the boundary wall [12], [13].

1.3. Presentation of data

1.3.1. Presentation of rainfall data

In general, precipitation and waters bring affecting almost all civil engineering projects, especially those involving water management because they constitute the main contribution to the water budget [12], [13]. Part of the department of Dakar, the rainfall in the town of Grand Yoff is almost as well known there the rainfall station Dakar-Yoff whose first recordings date back to 1947. As part of this project, we will use the rainfall set in the Master Plan of Drainage (PDA) for treatment of the problem of rainwater in Dakar. The core sample used in the PDD is composed of maximum daily rainfall data recorded at stations Dakar-Hospital (1896-1944) and Dakar-Yoff (1947-2009) [12], [13]. A first treatment was performed on the overall period (1896-2009), and a second for the period 1896-1969, that is to say the period during which rainfall was higher and probably more representative of the rainfall current. Given current trends in rainfall, which tends to be closer to that observed before 1970, it was used as the basis of the study. The value of daily rainfall are calculated over the period 1896-1969. PDD has used the work of Brunet-Moret [15]. which is based on the analysis of rainfall records and recordings of rain gages and aims to establish intensities, durations frequencies curves for various return periods on the entire Senegalese territory. The exploitation of these results are given in Table 1.

Table 1: Duration-Frequency-intensities

Return period time (h)	**Duration (h)**								
	0,25	0,5	1	2	4	6	8	12	24
	Intensity (mm/h)								
2 years	102	72	50	29	16,1	11,2	8,6	5,9	3,2
5 years	118	84	59	36,5	21,7	15,5	12	8,3	4,5
10 years	130	93,5	65	44	25,5	17,9	13,9	9,7	5,4

As part of the network audits, will be held a return period of 10 years. The return period is almost used in all design projects of hydraulic structures, especially in urban sanitation [12], [13], [14]. Indeed, given the high stakes and investment costs will have to realize that it is necessary to guarantee the local population sufficient security. Therefore, the equation used to calculate the intensities for verification is:

$$I = 17{,}558\, t^{-0{,}702} \qquad (1)$$

Where t is the duration of rain in minutes and I the rain intensity of the in mm/h.

1.3.2. Presentation of topographic data

The study of runoff implies precise knowledge of the topography, which, thanks to the principle that the water always dribbled down the slopes, is the element most critical to the knowledge of the directions taken by the runoff. Topographic data can be in two forms: the contour lines that connect points of equal elevation in a given area; listed points which are known points whose heights are marked on a map. In our study area, data were provided by the National Office for Sanitation of Senegal (O.N.A.S.) which is the service responsible for managing wastewater systems in most regions of Senegal, including Dakar. We have disposed of its Geographic Information System (GIS) that shows all network paths and contours of the study area. In addition, we used the Global Mapper software for processing data obtained from the GIS ONAS services and EPA SWMM software for hydrological simulations on the network.

1.4. Summary presentation of the Global Mapper software

Global Mapper is a mapping software developed by BLUE MARBBLE GEOGRAPHICS to make Digital Terrain

Models (DTM), flow simulations, zoning maps and delineation of watersheds and sub watersheds of a place given. It also allows to make a lot of network profiles delineate dependent surfaces and calculate their corresponding areas and performances in three (3) dimensions of the areas studied. With Global Mapper, we divided our basin into 13 sub-watersheds (BV) (Figure 2).

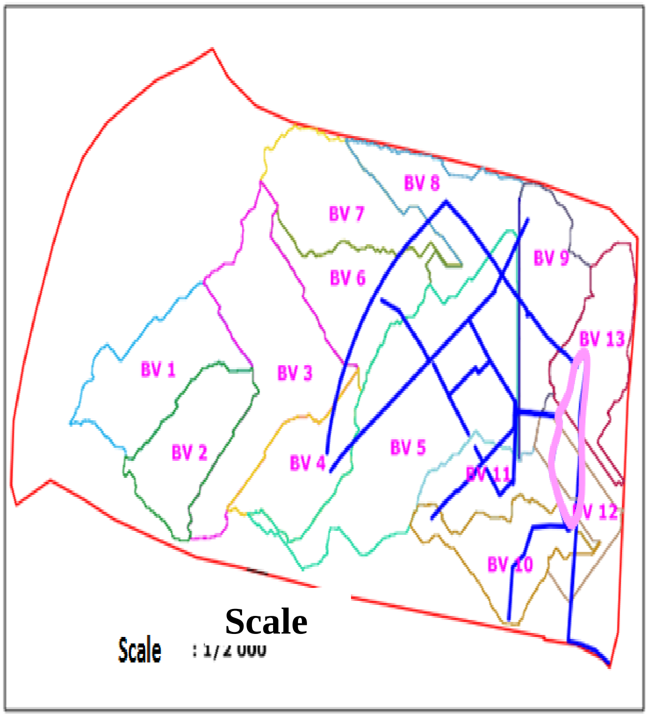

Figure 2: delineation of watersheds in the study area (BV : Watersheds)

The figure 3 gives legend of pipelines ensuring drainage of watersheds.

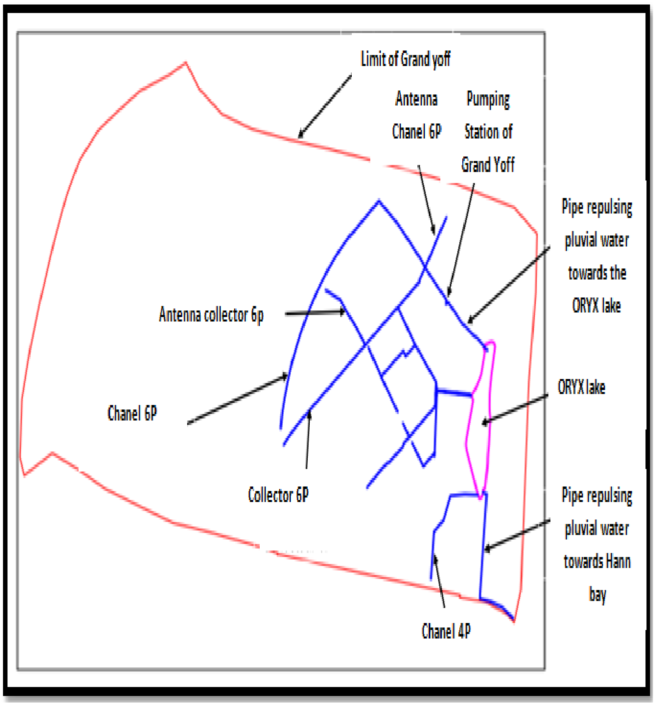

Figure 3: Diagram of network storm Grand Yoff

The table 2 below gives the size of each sub watershed.
Table 2: Areas of sub watersheds

Sub watersheds	Area in **km^2**	Area in **ha**
BV 1	0,3202	32,02
BV 2	0,2587	25,87
BV 3	0,5030	50,30
BV 4	0,2366	23,66
BV 5	0,7900	79,00
BV 6	0,2824	28,24
BV 7	0,3287	32,87
BV 8	0,2840	28,40
BV 9	0,2768	27,68
BV 10	0,2421	24,21
BV 11	0,2051	20,51
BV 12	0,1440	14,40
BV 13	0,2510	25,10
Total area	**4,1226**	**412,26**

In terms of estimating runoff and volumes waters, we used the EPA SWMM [16], [17], [18]. software to analyze the impact of the network on the floods.

1.5. Summary presentation of the EPA SWMM 5.0 software

The EPA SWMM software (Storm Water Management Model) is a software-oriented precipitation or by precipitation simulation and flow during a single event or by continuous simulation of the quantity and quality of flow, mainly in urban areas. This software was created in 1971 and has since experienced many improvements. Nowadays, it is used around the world. Indeed, because of the physical parameters, it requires and do not hold it against the location of the basin to be studied, it is widely used today in Senegal. Version 5 is produced by the US Environmental Protection Agency with the assistance of a consulting firm Camp Dresser & McKee Engineering Inc. In addition, EPA SWMM uses hydrological models such as Horton, Green Ampt, Curve Number etc. We used the model Curve Number, which is the most suitable for the calculation of seepage losses and net resulting rain runoff. The input parameters are existing data that allow us, once we introduce in the software, making a runoff simulation watershed and have the runoff water volumes and volumes for a given infiltrated rain [16], [17], [18]. These parameters are project rains which are defined by asynthetic hyetogram and statistically equivalent to the actual rain that never observed [19], [20], [21] [22], [23], [24], [25], [26], [27], [28], [29], [30]. In the PDD, the return period of design storms T = 10 years were defined. We use them to diagnose the network. They are five in number (5) and are the following: four (4) short rains, developed under the double-delta method, characterized by their intense periods: 15, 30, 60 and 120 minutes, a total of 4 hours, a long rain, Kieffer type over a period of 24 hours. Table 3 gives the rain height depending on the rain type.

Table 3: Height of the chosen design storms

Rain types	4H-15 mn intense period	4H-30 mn intense period	4H-60 mn intense duration	4H-120 mn intense duration	Kiefer Type duration 24 H
Height (mm)	101,94	102,03	102	102	129,8

The network consists of collectors (3), impoundment of storm basin and discharge or lift station. An outlet is a discharge point where converge the water of a watershed, in other words, the point of water collection. Here, Hann Bay is the outlet that is used to reject the waters of the catchment area. Its distance from the basin of the catchment area is 2360.4 m.

2. RESULTS AND DISCUSSION

Given the objective, we will undertake verification of main collectors in a one, taking care to estimate the values of the necessary parameters. This check cannot be done without the prior one has made certain assumptions that are indispensable for the application of the methods used and formulas. The conditions of application of the rational method with uniform intensity are carried out: the slope of the trough along a section is considered constant. It ignores the uneven terrain and therefore its holding capacity; the Manning-Strickler formula in the case of a uniform flow is applicable for determining the capacity of sections. Therefore, the flow is assumed constant and uniform along a section; the maximum filling rate admitted in the pipes is 100% of the section; the audit will involve some major collectors.

The capacity of the sections Qp is given by:

$$Qp = V.Sc \qquad (2)$$

Where V is the average flow velocity in the section (m / s) and Sc the flow area (m^2). The average flow velocity is obtained ccording to Manning-Strickler :

$$V = K_S . R_H^{2/3} . i^{1/2} \qquad (3)$$

Where Ks is the Strickler coefficient selected from Table 4 depending on the materials which constitute the pipes. Here we take Ks equal to 70 due to the obsolescence of collectors; R_H is the hydraulic radius obtained by the ratio of the wet section on the wetted perimeter and i the slope of the channel section;

Table 4: Coefficients of Strickler

Ordinary concrete	Masonry	walls damaged	plastic	iron, steel
70	60	50	80	70

To check the sections of main collectors, the calculation steps are the determination of the parameters used in the relations giving the rates for collectors. That is to say concentration time: tc obtained by this following formula tc= tr + te (min); S the drainage area (ha); C the runoff coefficient (-); L the length of the trough (km); I the rainfall intensity (m/h); j the slope of the watershed (-); tr the run time (mn); te the flow time (mn) and Q the flow runoff (m^3/s)

Table 5 summarizes the characteristics of sub-basins.

N° Basin	**Area in ha**	**C**	**Long. Trough (m)**	**upstream Shore (m)**	**downstream Shore (m)**	**Slope (%)**	**t_r**	**I (mm/h)**	**Q (m^3/s)**
BV1	32,02	0,57	984	42	29	1,32	20,79	125,15	6,35
BV2	25,87	0,57	814	38	27	1,35	17,81	139,52	5,71
BV3	50,3	0,57	1 125	38	20	1,60	21,41	122,60	9,76
BV4	23,66	0,57	596	38	22	2,68	10,76	198,78	7,45
BV5	79	0,64	1 098	25	11	1,28	22,94	116,83	16,41
BV6	28,24	0,57	626	33	20	2,08	12,33	180,59	8,07
BV7	32,87	0,57	941	35	15	2,13	16,73	145,79	7,59
BV8	28,4	0,57	612	29	15	2,29	11,68	187,66	8,44
BV9	27,68	0,64	143	13	11	1,40	4,61	360,51	17,74
BV10	24,21	0,64	592	19	10	1,52	13,32	171,08	7,36
BV11	20,51	0,64	223	18	15	1,35	6,58	280,58	10,23
BV12	14,4	0,64	323	9	8	0,31	15,42	154,40	3,95
BV13	25,1	0,64	566	15	9	1,06	14,78	159,01	7,10

Considering the calculation example of chanel 6p. It is a long chanel 1 935.74 m along the road Niayes to just before the “bridge of the emergence”. There are two types of section: a rectangular dimensions of 1.5 m × 1.1 m to 2 m x 1.1 m reinforced concrete and a circular section of diameter 1.8 m unreinforced concrete or asbestos cement. It is completely buried. Given the variable sections, we have divided into five (5) sections for verification of sections capabilities. The total drainage area is 249.04 ha.

For the first section, a rectangular one :

b = 1.5 m; h = 1.1 m; ($b_=$width of the chanel and $h_=$ height of the chanel)

Length: Lc = 131.882 m;

Slope of conduct: i = 0.45%;
runoff coefficient C = 0.57 and coefficient of Strickler: KS = 70;
Drainage area (surface BV4): S = 23.66 ha and sloping land: j = 2.68%;
Thalweg length L = 596 m;
For the remaining sections, the calculations were carried out in the same manner as above and the results are provided in Table 6:

Table 6 : Ability of sections of Canal6p

Sections	width (or diameter) (m)	Height (m)	**Length. (m)**	Slope (%)	**K_s**	**S_m (m^2)**	**P_m (m)**	**R_H (m)**	**V (m/s)**	**Q_P (m^3/s)**
1	1,5	1,1	131,882	0,45	70	1,65	3,70	0,45	2,74	**4,52**
2	1,8	1,1	313,356	0,41	70	1,98	4,00	0,50	2,80	**5,55**
3	2	1,1	827,561	0,68	70	2,20	4,20	0,52	3,75	**8,25**
4	1,8	0	382,485	0,66	70	2,54	5,65	0,45	3,34	**8,50**
5	1,8	0	280,451	1,18	70	2,54	5,65	0,45	4,47	**11,36**

For the calculations, the results are given in Table 7.

Table 7: runoff rate for each section of Chanal 6p

N° Basin	Sections	Areas(ha)	Speed (m/s)	Length pipe (m)	**t_e (min)**	**t_r (min)**	**t_c (min)**	**I (mm/h)**	**C**	**Q (m^3/s)**
BV4	**1**	23,66	0	0,00	0	10,76	10,76	198,78	0,57	**7,45**
BV_{1234}	**2**	131,85	2,74	131,88	0,80	42,21	43,01	75,14	0,57	**15,68**
BV_{12346}	**3**	160,09	2,80	445,24	2,65	54,54	57,19	61,52	0,57	**15,59**
$BV_{1234678}$	**4**	221,36	3,75	1 272,80	5,66	66,22	71,87	52,40	0,57	**18,37**
$BV_{12346789}$	**5**	249,04	3,34	1 655,28	8,26	70,82	79,08	49,00	0,57	**19,32**

In summary, we find that, from Tables 6 and 7, on all sections of the Chanal 6p, overlowing is marked explaining by rates far exceed the capacity of the sections. Table 8 shows that.

Table 8: flow comparison table for Chanal 6p

N° Basin	**sections**	drained Areas (ha)	**Q_P (m^3/s)**	**Q (m^3/s)**	Load factor
BV4	**1**	23,66	4,52	7,45	**165%**
BV_{1234}	**2**	131,85	5,55	15,68	**282%**
BV_{12346}	**3**	160,09	8,25	15,59	**189%**
$BV_{1234678}$	**4**	221,36	8,50	18,37	**216%**
$BV_{12346789}$	**5**	249,04	11,36	19,32	**170%**

After checking the flow conditions Chanal 6P and network collector 6p, we find that: i) the Chanal6P length 1 935.74 m, has exceeded its capacity throughout its length with speed differentials of over 200%; ii) the Collector 6P also has the ability which is well below the steam rates with occupancy rates exceeding 185% on average.
To alleviate the overflow of Canal6P and Coll6P collectors, necessary in the coming years to devise additional branches decreasing their tributaries surfaces would relieve the excess flow that is seeking.

III. CONCLUSION

The general objective of this paper was to verify the ability of Grand Yoff drainage compared to flooding, in other words, to analyze its real impact in the fight against the past that have become a headache for the people surrounding. This audit allowed us to show the obsolescence of some collectors whose abilities are substantially exceeded in relation to runoff they can evacuate. Note that the drainage of storm water existing in our study area has views limits the large amounts of water collected versus the one hand to the small size of the catchment area impoundment, outlet of most coastal watersheds, and also compared to antiquated collectors who

can no longer bear all the amounts of water following a ten-year rain event. In general, the rainwater drainage network of the town of Grand Yoff is overall undersized. Overflows are to be expected even during non-decennial events. This is why a new drainage network is proposed to improve the situation in this area in the fight against floods.

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